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THE INFLUENCE OF EXTERNAL PACING ON LEARNING FROM PROGRAMED INSTRUCTION, REPORT 2--STUDIES IN TELEVISED INSTRUCTION, INDIVIDUALIZING GROUP INSTRUCTION.

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THE EFFECTS OF VARIATIONS IN EXTERNALLY DIRECTED TEMPO (OPPOSITE OF SELF-PACING) ON PROGRAMED LEARNING PERFORMANCE WERE INVESTIGATED. THIS REPRESENTED THE SECOND IN A SERIES OF THREE STUDIES CONCERNING THE RELATIONSHIP BETWEEN PACING MODE AND BEHAVIOR. (REFER TO ACCESSION NUMBERS ED 003 199, ED 003 201, AND ED 003 202 FOR ADDITIONAL INFORMATION ON THIS PROJECT.) THE 277 SUBJECTS WERE EIGHTH-GRADERS DRAWN FROM 8 SEPARATE CLASSES. LESSON MATERIALS CONSISTED OF SELF-PACED PHYSICS PROGRAMS ADMINISTERED IN SCHOOLS PRIOR TO THIS EXPERIMENT ON FIXED PACING. PROGRAMED MATERIALS (PHYSICS) WERE PRESENTED AT A FIXED PACE DURING THE MAIN EXPERIMENT AT A TELEVISION STUDIO. FINDINGS WERE--(1) INCREASES IN TEMPO PRODUCED PERFORMANCE DECREMENTS, (2) UNDER FIXED TEMPO CONDITIONS, STUDENTS VARYING IN ABILITY AND WORK RATE WERE IMPAIRED, AND (3) GROUP PERFORMANCE UNDER SLOW, FIXED TEMPOS WAS SUPERIOR TO GROUP PERFORMANCE UNDER SELF-PACED CONDITIONS. THESE RESULTS WERE DISCUSSED IN TERMS OF RECOMMENDATIONS FOR SITUATIONS IN WHICH SELF-PACING OR FIXED PACING CAN MORE APPROPRIATELY BE USED. (JC)

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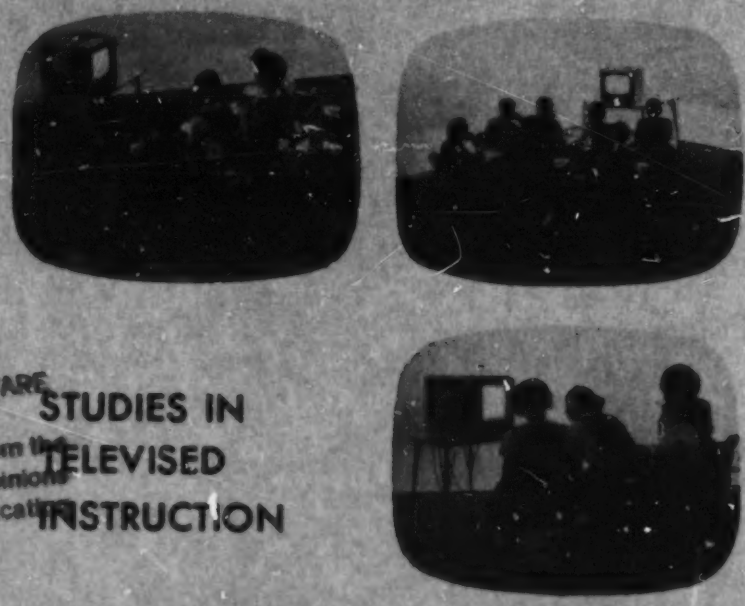

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STUDIES IN TELEVISED INSTRUCTION

INDIVIDUALIZING GROUP INSTRUCTION

2. THE INFLUENCE OF EXTERNAL PACING ON LEARNING FROM PROGRAMMED INSTRUCTION

Gerard C. Kress Jr.
and
George L. Gropper

METROPOLITAN PITTSBURGH EDUCATIONAL TELEVISION STATION
and the AMERICAN INSTITUTES FOR RESEARCH

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STUDIES IN TELEVISED INSTRUCTION
individualized group instruction

Report #1 - Individual differences in learning from self-paced programmed instruction.

Report #2 - The influence of external pacing on learning from programmed instruction.

Report #3 - Accommodating individual differences during externally-paced programmed instruction.

Report #4 - A summary report.

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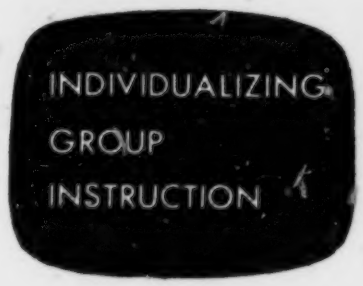
STUDIES IN TELEVISED INSTRUCTION



2. THE INFLUENCE OF EXTERNAL PACING ON LEARNING FROM PROGRAMMED INSTRUCTION

Gerard C. Kress, Jr., Project Director
and
George L. Gropper, Principal investigator

NOVEMBER 1964

METROPOLITAN PITTSBURGH EDUCATIONAL TELEVISION STATION
and the AMERICAN INSTITUTES FOR RESEARCH

FOREWORD

The research reported in this volume was conducted under a grant from the U. S. Department of Health, Education, and Welfare, Office of Education, under title VII, the National Defense Education Act of 1958, Project No. 637, Grant No. 7-36-120.01. Data analyses were partially supported by a National Science Foundation grant (No. G-11309) to the University of Pittsburgh Computing Center.

The proposal for this project was based on an award-winning research plan submitted by the Principal Investigator to the Television Research Plans Competition sponsored by the Television Bureau of Advertising (Gropper, 1963)*.

The authors are grateful to numerous people for their participation and cooperation in this project including: Dr. Evan Ingram of the Pittsburgh City Schools and Sister Rosalie of the Diocesan Schools in Pittsburgh for their help in enlisting the participation of pupils and teachers in this project; to the staff of WQED for their work in the production of televised lessons used in the project; to Charlotte Conley and Martha Scott for their aid in reproducing this report; and to Margaret Samways and Zita Glasgow for their preparation of programmed materials used in the study.

George L. Gropper
and
Gerard C. Kress, Jr.

December 1964

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*Gropper, G. L. An experimental evaluation of procedures for "individualizing televised instruction. In L. Arons & M. A. May (Eds.) Television and Human Behavior - Tomorrow's research in mass communication. New York: Appleton-Century-Crofts, 1963.

ABSTRACT

This study is concerned with the effects of fixed pacing on student performance on a connected-discourse, verbal program. The Ss were eighth-grade students. The subject matter was physics. The primary findings were: (1) increases in fixed tempo produced performance decrements; (2) under fixed tempo conditions, students varying in ability and characteristic work rate were impaired differentially; and (3) group performance under slow, fixed tempos was superior to group performance under self-paced conditions. These results led to practical recommendations as to the situations in which self-pacing or fixed pacing can more appropriately be used.

The pace at which a student works on a program can be non-adaptive whether it is self-adopted or externally imposed. On the one hand, it can be too fast to be compatible with high achievement. On the other, it can be too slow to be compatible with learning efficiency. Individualization of instruction, it is suggested, can best be attained by the pacing strategy, self-pacing or fixed pacing, that can maximize both learning effectiveness and learning efficiency. For those self-paced students who adopt too fast a pace, slow fixed-paced programs appear indicated. For those self-paced students who adopt too slow a pace, faster fixed-paced programs appear indicated, but only if they demonstrate that they can adapt to the speed-up. Self-pacing might best be reserved for those students for whom both achievement and efficiency are thereby maximized. Thus, individualization need not be thought to depend on who sets the learning pace. Whatever the pacing mode, individualization occurs only when learning effectiveness and efficiency are realized.

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INTRODUCTION

On the basis of a recent exhaustive review of research on instructional television, Schramm (1962) concluded that the instructional capability of the television medium has been more than amply demonstrated. The question still remains: Can television do a better job than conventional, classroom instruction? Of the 400 studies which Schramm reviewed, very few reported significant differences in achievement between students receiving televised and students receiving conventional instruction. In view of the fact that the overwhelming majority of the televised lessons were simply conventional lectures, mediated electronically, the failure to find differences is not surprising.

Future research on instructional television would seem more properly concerned with an analysis of its distinctive capabilities rather than with comparisons between it and non-televised instruction. Newly oriented research would be aimed at identifying television's inherent difficulties and means for overcoming them as well as at identifying and exploiting its inherent advantages. One of the major disadvantages of instructional television, which has already been identified, is its often cited tendency to promote student passivity. A class viewing a televised lesson can easily become an "audience" which participates in the learning process but superficially. The problem is not unique to television. It has been observed in instruction by film and has been the subject of similar criticism. Typically, there is in both situations little opportunity for student involvement; questions are neither directed toward individuals, nor are answers forthcoming to questions which might occur to them. To offset the instructional disadvantages created by the absence of such opportunities, efforts have been made in some filmed instruction to provide student involvement. Several studies have demonstrated that lessons which have student participation techniques built into them are superior to those employing the conventional lecture approach, (Allen, 1957; Hoban, 1950; & Miller, 1957).

Since the instructional capabilities of the film and television media are very similar, it was reasonable to expect that participation techniques could be used to improve the effectiveness of televised lessons as well. Indeed, direct evidence to this effect has already been reported. Gropper and Lumsdaine (1961), for example, found that learning was enhanced when questions were built

into the televised presentation at key points, with all students given the opportunity to respond, either overtly or covertly. In another portion of the same study, Gropper and Lumsdaine carried the active participation feature much further. This was done by applying techniques of programmed instruction to televised lessons. A similar application was made by Carpenter and Greenhill (1963). In both instances, this involved the usual programming approach of specifying objectives, developing sequences of steps, requiring students to respond actively at each step, and supplying them with immediate confirmation. Save for a self-pacing provision, the lessons were thus fully programmed in the teaching machine sense. Gropper (1962) extended this same general approach to nonverbal science demonstrations in which student responses were made to visual events. Students actively participating in instructional settings of this kind can hardly be characterized as passive recipients of instruction.

Although the results of these several studies were generally favorable, the marriage of programming techniques which were designed for individual presentations and television which was designed for group presentations created a practical problem: how to accommodate individual differences in the amount of time required to complete each frame or step in the program. Heterogeneity in time requirements is usually handled in programmed instruction by allowing each student to proceed at his own pace. In this way, it has frequently been pointed out, more able students are free to work rapidly and less able students can take as much time as they need. Ideally, all students, as a result, reach similar criterion behavior and differ only in the rate of acquisition, not in amount. This self-pacing capability of programmed instruction is generally held to be one of its prime advantages. Any extension of programming techniques to group instructional settings which do not have such a self-pacing capability must come to grips with the problem of selecting a uniform rate of presentation which is appropriate for the entire group. The results presented in the first report in this series (Kress & Gropper, 1964) further complicate the issue by demonstrating that even self-selection of a working pace may not result in as uniformly high achievement as is idealized. Since it is possible for students to adopt a pace inappropriate for their individual needs, use of self-adopted paces as an estimate of what the group pace ought to be has its pitfalls.

There is a reasonable consensus among programmers favoring Skinner's (1954) view that it is important that students practice correct responses if high

achievement levels are to be attained. In practice this typically means that the difficulty level of a program is revised until the less able students respond correctly. In addition, when the program is presented to students individually, students can spend more time on those portions of the lesson which pose greater difficulty for them personally. When a program is presented to students as a group, however, this is no longer possible. One pace must be selected for all. Unless that pace is slow enough for the member of the group requiring the most time, it has been generally assumed that the program will fail to accommodate the ability of someone. However, if it is made slow enough for the slowest member of the group, it has also been generally assumed that the lesson will be too slow to be either challenging or efficient for the faster students.

It is instructive to review the few studies which have actually presented fixed-paced programmed lessons to groups and to examine the evidence as to the effect which external pacing has on student achievement. The evidence and conclusions based on it appear to be somewhat contradictory.

Studies in Which a Fixed Pace Did Not Depress Achievement

Feldhusen and Birt (1962) working with college students found no detriment to achievement when the experimenters controlled the tempo or rate of presentation at which a 37-frame linear program was presented. The tempo selected by the experimenters was based on the average time per frame required by a separate pilot group which worked at a self-selected pace. Times on the frames in the program (as obtained from the pilot group) ranged from 30 to 50 seconds. The externally paced experimental group was compared with eight self-paced groups whose presentations varied as to device employed, whether or not feedback was provided, and whether or not constructed responses were required. The analysis of achievement scores (corrected for pretest level) indicated no significant differences between self-paced and externally paced groups.

A second study in which college students were given fixed-paced programmed instruction was conducted by Silverman and Alter (1961). Two fixed-paced groups, one called "paced" and the other "long paced" were compared with a self-paced group on an 87-frame linear program. The tempo employed in the "paced" group was described as, "congenial to most Ss as determined by preliminary testing for an optimum presentation rate." The "long-paced" group was allowed more time than was judged necessary to complete frames. No significant differences

were found between either fixed-paced group and the self-paced group, nor between the two fixed-paced groups. The writers concluded that, "Pacing the learner will not impair his performance if care is taken to ascertain optimal pacing rates."

In another study by the same writers (Alter & Silverman, 1962), college students were again presented programmed instruction at externally fixed tempos. The 87-frame linear program used in the previous study was also used in this study. Pacing (fixed or self) was a variable crossed with response mode, in a 2x2 factorial design. Although the mean achievement scores adjusted for pretest scores were slightly higher for the fixed-paced groups, no significant difference was found between fixed- and self-paced groups.

The Carpenter and Greenhill (1963) study included two experiments in which external pacing and self-pacing were systematically compared. In the first, 26 college students were presented an externally paced, 15-unit mathematics course. Their final achievement scores proved to be not significantly different from those of two self-paced groups of 28 students each. In this comparison, the exposure time selected for each frame was the average time spent by a group of pilot Ss who had worked at their own pace. A second experiment was performed to assess the effect that varying presentation tempos had on the performance of 180 college students who took six programmed mathematics units. The four tempos selected were 80, 90, 100, and 110 per cent of a base tempo. Base tempo on each frame was defined as the mean time required by a pilot group which went through the same programs at a self-adopted pace. Measures were obtained both of achievement and of attitude toward instruction as a function of the varied tempos. Analyses of both measures showed a small but not significant drop in mean scores as tempo increased. The authors concluded that rate of presentation within the limits observed does not critically influence achievement or attitude. They indicated, however, that the 80 per cent of base tempo seemed to approach a practical limit. More generally, on the basis of both experiments, they concluded that college students can tolerate a wide range of tempos and further speculated that learning efficiency may be enhanced by a progressive increase in tempo.

A 1959 study by Briggs, Plashinski, and Jones compared self- and machine-pacing employing a 20-item paired-associate learning task. The subjects in this instance were Air Force personnel. Self-pacing and machine-pacing (fixed)

were not found to yield any difference in achievement. Although the learning task was different from that in programmed instruction, the absence of an effect attributable to pacing mode was consistent with the other studies just cited.

Generally the results of the several experiments just described have shown that within modest limits, it seems not to matter for the effectiveness of programmed instruction that Ss were required to work at an externally determined pace and were not free to adopt their own working pace.

Studies in Which a Fixed Pace was Associated with Depressed Achievement

Follettie (1961), using programs on land warfare and first aid, found self-pacing to be superior to fixed-pacing as reflected in test score, test time, and training time. With results expressed in terms of efficiency measures, learning was depressed by the imposition of external or fixed-pacing. This may have been due to the fact that the tempo for the fixed-paced condition was selected on the basis of the average reading rate of the group, and thus was faster than would have been chosen by the slower readers under self-paced conditions.

The 1961 study by Gropper and Lumsdaine compared a programmed lesson given at a fixed pace with a conventional lecture version of the same lesson. While no direct comparison was made between fixed-pacing and self-pacing, their overall results were interpreted to mean that learning was depressed by a single program presented at a single tempo. This interpretation was based on the finding that, while the programmed lesson resulted in achievement significantly superior to the conventional lesson, the superiority stemmed from only the high IQ students. The higher ability Ss showed larger gains from the programmed lesson, while the less able failed to differ from their counterparts who viewed the conventional lesson. Thus, a single programmed lesson, presented to a heterogeneous group at a uniform tempo, may not have been adequate to accommodate the wide range of ability encountered. These writers suggested that separate program sources for selected groups might enhance the effectiveness of fixed-paced programmed instruction.

A 1963 study by Frye appears relevant to that suggestion. The materials used in the study consisted of a 47- and an 88-frame program designed to teach quadratic equations. Since each S was required to review frames, if necessary, until perfect criterion performance was achieved, the dependent variable was

not achievement, but acquisition time. The purpose of the study was to observe the effects of both fixed- and self-paced programmed instruction upon groups which were deliberately selected to differ in spread of ability, but not in mean ability level. Ability was defined by scores on the Primary Mental Abilities Test and the Orleans Algebra Prognosis. From the overall ability distribution, Ss in the upper and lower quartiles formed two groups called "heterogeneous." The Ss in the middle quartiles formed two groups called "homogeneous." Each of the two kinds of groups was then assigned to either a self-paced or a fixed-paced learning condition. In the fixed-paced condition, all Ss began each frame together after the slowest S had finished the preceding frame. The time allotted each frame was thus the same for everyone in the group. It was determined not by the experimenter but by the last finisher on each frame. By administering fixed and self-paced instruction to both homogeneous and heterogeneous ability groups, four conditions of learning were thus compared.

Frye found that requiring Ss to work as a group did not impair efficiency when the group was homogeneous in ability. The overall time required by this group was not significantly greater than the time required by either of the self-paced groups. On the other hand, when the group members differed widely in ability, a fixed pace led to a much less efficient learning situation: the heterogeneous fixed-paced group required significantly more time than did either of the other three groups.

These results appear to support the notion that external control over pace in group instruction is not detrimental per se, but can be if the members of the group are of dissimilar ability. Further, they partly confirm the efficacy of the Gropper and Lumsdaine suggestion of presenting separate program sources to selected groups, since a fixed pace was clearly more effective for the homogeneous group. In addition, these results concerning group homogeneity vs. heterogeneity are suggestive in explaining the apparently discrepant conclusions found in the literature concerning the effects of external pacing.

One feature which appears to have been systematically different between the studies which found external pacing detrimental to performance and those which did not was the range of ability of their respective subjects. It will be recalled that the studies in which external pacing was judged to be as effective as self-pacing, namely the studies by Silverman and Alter, Alter and Silverman, Feldhusen and Birt, and Carpenter and Greenhill, all employed college students as Ss. On the other hand, of those investigators who found external

control over students' learning pace not to be as effective, not one used a college group. Folletie worked with military trainees, Gropper and Lumsdaine with junior high school pupils, and Frye with high school freshmen.

Apart from their generally higher level of ability, college students represent a relatively screened group, much more homogeneous in ability than is true of 8th and 9th graders or military trainees. It will be remembered that the results of the Frye study indicated that when the range of ability is wide, a single pace for the group is not consistent with efficient learning. In addition, they showed that when the range is narrow, the single, fixed pace seems to be just as efficient as self-selected paces. It seems reasonable then, to conclude that one reason for the apparent inconsistency of results about the effects of external vs. self-pacing is that the two groups of studies reviewed dealt with groups of subjects which differed sharply in their ranges of ability.

These results may be interpreted in a slightly different way. The difference in pace between that <u>imposed upon</u> the group (based upon the group average) and that which would have been <u>adopted by</u> the group if given the option, was likely a much smaller difference in the homogeneous groups than in heterogeneous groups. The more drastic nature of the increase or decrease in rate of work caused by the use of an average tempo in a heterogeneous group may well be the factor determining whether there will be decrement in performance or efficiency. The results presented in Report #1 of this series would lead to the prediction that performance decrement would most likely reside primarily among students who characteristically adopt slow work rates, efficiency decrement among students who characteristically adopt fast work rates and who, at the same time, demonstrate high achievement.

<u>"Tempo" and Active Participation in Group Instruction</u>

From the several studies considered above, it is apparent that the "programming" of instruction can be applied in group settings to some advantage. Undoubtedly, the observed superiority of such an approach over that found in the conventional lesson is due both to the analytic conception involved, to the design and preparation of lesson content itself, and to the involvement of the student overly practicing responses and receiving frequent feedback. However, the way in which such practice is scheduled, dictated by the tempo at which frames are presented, is a feature of the approach about which very little is

known. It has been demonstrated that giving the individual the opportunity to adopt his own pace may not be critical per se, but that pace which is based on the average of a group may not qualify as "optimal" for all members of a group. Few studies have been performed to observe the effects of systematically varied tempos and their interaction with individual ability measures.

Varations in tempo. - The 1961 study by Silverman and Alter observed the effects of two levels of (fixed) tempo. A "paced" and a "long-paced" group were compared. As noted earlier, the tempo for the "paced" group was described as providing adequate time for most Ss while that of the "long-paced" group was described as providing more time than most Ss required. It will be recalled that the two tempos failed to affect performance differentially, nor did Ss receiving either treatment differ from Ss in self-paced groups. The Carpenter and Greenhill studies included an experiment in which four fixed-tempo levels were compared. They were set at 80, 90, 100, and 110 per cent of the average self-adopted tempo of a pilot group. As noted earlier, none of these tempo levels led to performance which was significantly different from any other.

To summarize, no particular effect on performance has been observed as a result of variations in fixed tempo. It seems fair to say, however, that the limits within which tempos have been varied in these studies have been modest considering the typical range of times required by Ss who are given the option to adopt their own pace.

Range of time required. - Based on the results of various studies on self-paced programmed instruction which report time data, the consensus appears to be that a fairly wide range of times are required to complete a given program. Skinner and Holland (1958), for example, report wide fluctuations among college Ss in time required to complete a programmed supplement to the Natural Sciences 114 course. The easiest program resulted in a median time of eight minutes, with a range of five to thirteen minutes. The most difficult required a 20-minute median time, the range being 10 to 48 minutes. High school Ss working through a 61-frame, multiple-choice response program, were observed by Silberman, Melaragno, Coulson, and Estevan (1961), to require a mean time of 32.8 minutes. The standard deviation was 10.7 minutes, indicating that even among the middle 2/3 of the group some Ss required twice as much time as others. A 1962 report by Cook presents the time data for 12 high school subjects working with a fairly large amount of programmed material (800 frames). Time required to complete

the program ranged between approximately six and fifteen hours. This reflected a frame-per-hour rate of 127 to 54 respectively.

A much younger group was observed by Shay (1961). The time data from his fourth-grade sample was reported by levels of IQ. The mean time to complete a 199-frame (small step size) program was 90 (SD = 19.3) and 135 (SD = 42.5) minutes for the above and below average IQ groups, respectively. For the group as a whole, individual time requirements are seen to have been extremely variable.

The findings based on the self-paced Atomics and Force Programs used in the present series of studies (Kress & Gropper, 1964) were in good agreement with those just reviewed. The wide range of individual Work Rates encountered may be found in Report #1. None of these reported time ranges is surprising, the fact of wide variation in time requirements having long been cited as a central feature of programmed instruction. They serve to illustrate, however, that the range of fixed tempos which has been observed in studies on effects of fixed pacing, for example, 80 to 110 per cent of the group average, is very small indeed when compared with the range of self-adopted tempos (work rates) which is typical of most groups. For a fuller understanding of the effect which a fixed pace may have on learning, the use of a wider range of fixed paces more closely approximating the range of self-adopted paces appears indicated.

Purpose

It is the purpose of the present experiment to explore the effects on student performance of a wider range of fixed tempos than has been employed in experiments performed to date. In addition, individual differences in response to such variations in tempo will be identified and measured. A study of the effects of variations in tempo and the identification of the kinds of Ss for whom they are more or less pronounced, can provide guidelines for the assignment of students to specially constituted subgroups. Such groups could be offered lessons employing tempos specifically designed to optimize their learning experience.

It is generally hypothesized that the imposition of increasingly fast tempos will be accompanied by a progressive increase in errors and, consequently, a decrease in achievement. This expectation appears reasonable since the performance of an increasing proportion of the sample will suffer as the pace begins

to exceed the pace it would characteristically adopt for itself if allowed to do so. The decrement which occurs is thus expected to be non-uniform, since the samples will be composed of Ss of widely differing both in ability and in their own characteristic work rate.

It will be recalled from Report #1 in this series that work rates were stable for both high and low achievers. Obviously, the work rate of low achievers bears no clear relationship to their rate of acquisition. There is no reason, therefore, to expect that their work rates have any relevance to their ability to resist the detrimental effects of a speeded tempo. The work rates of the high achievers, whether fast or slow, on the other hand, represent self-adopted paces which permit achievement to occur. Therefore, a high achiever who worked at a very rapid self-adopted pace would be expected to be able to work more rapidly without decrement when the pace is controlled externally than would one who worked at a very slow self-selected pace. Partly at least, because IQ and work rate bear a moderate negative relationship to one another, it might also be expected that higher IQ Ss would also be more likely to resist the effects of increased tempos than could their less able fellows.

In summary, the primary purpose of this study is to assess the effects of variations in tempo on performance. In addition to assessing these main effects, any significant interactive effects of tempo and either work rate or IQ which are revealed can provide useful information concerning the makeup of sub-groups which might be constituted to receive "individualized" group instruction.

METHOD

Subjects

The Ss who participated in this experiment consisted of 277 eighth-graders. This sample of Ss was drawn from a total of eight separate classes in four Pittsburgh city schools, two public and two parochial.

Materials

Lesson materials used in this study consisted of self-paced programs which were administered in the schools prior to the experiment on fixed pacing and a set of programmed materials which were presented at a fixed pace during the main experiment at the television studios of WQED.

Self-paced programs. - A total of three short programmed lessons was prepared for administration in the schools. One was a program on programs, the other two on the concepts of "force" and "atomic structure." Their purpose was to familiarize the Ss with programmed instructional materials and to provide a measure of each S's work rate. All of these programs are reproduced in their entirety in Report #1. Briefly, they can be described as being linear programs, requiring constructed responses, building discriminations and generalizations through the use of multiple examples, employing vanishing cues, and generally requiring longer and more complex responses as cuing is reduced.

Fixed-paced program. - The program employed in the fixed-paced group presentation was 96 frames in length covering some basic concepts of electricity. It dealt with the attraction and repulsion of particles, current as a flow of electrons, batteries, and voltage. The electricity program and its criterion achievement test are presented in Appendix A. As was true of the preliminary self-paced programs, the electricity program was linear and required constructed responses in every frame. The verbal content was augmented wherever deemed appropriate by line drawings and other similar visual prompts. The program was tried out with a pilot group representative of the target group which would participate in the experiment proper. It underwent several stages of revision until low error rates and high achievement levels resulted.

Following the final revisions of the program, steps were taken to determine the values of the fixed tempos to be employed in the main experimental comparisons.

The first step taken was to determine the time requirements for each frame based on the performance of a group of pilot Ss who worked through the program at a self-adopted pace. A total of 28 eighth-graders was selected from two schools to serve as pilot Ss. A wide range of abilities was represented in this group with Otis IQ's ranging between 87 and 125. Subjects were run in two groups: n = 15 and n = 13, with each group participating in the overall procedure for a total of four days.

On Day 1, pretests on Force, Atomics, and Electricity were administered plus a short Preprogram. On Day 2, Ss were familiarized with recording apparatus which was employed during each of the last three days. It consisted of a small wooden box at each desk with a hinged lid. When raised, the lid activated a switch which, in turn, tripped the pen of one channel of a multi-channel Event Recorder.[1] The box was designed to receive each frame in the program serially. Each frame in the program was reproduced on cards and arranged in a packet such that frame 1 appeared at the top, followed by frame 2, etc., through the last frame. A matching confirmation packet was arranged similarly in an upright holder. The task was as follows: (a) Ss began work on frame 1 at E's signal; (b) when each S finished writing his response on the card, he then raised the lid on the box and put the card into the box; (c) the confirmation card was drawn from the holder and S checked his answer; (d) when finished, S again raised the lid and put the confirmation card into the box; and (e) frame 2 was begun. This sequence was repeated until the last confirmation card was put into the box. In this manner, a complete time record was obtained for each S on every frame and its confirmation. The first program taken in this fashion was Atomics, followed by the Atomics Posttest. On Day 3, the Force Program and Posttest were given in similar fashion.

The first three days served to familiarize Ss both with learning from programmed materials and with the use of the timing apparatus. By Day 4 the novelty effect appeared to have dissipated and Ss were working in routine fashion on the material of primary interest: the Electricity Program and Posttest. A distribution of times was obtained from 23 Ss who were present on the fourth day of the procedure for each frame of the Electricity Program. The

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[1]Manufactured by the Esterline-Angus Company

posttest scores of these Ss ranged from 65 to 100 percent. The times of one S who was present were omitted inasmuch as she achieved a posttest score of only 35 percent. Her times could therefore not be judged to represent a valid or appropriate work rate capable of producing minimally acceptable achievement levels. (The issue of "valid" work rates will be treated again in a later section.)

The selection of exposure times for each of three presentation tempos was based on the distribution of the time Ss took on each frame. Inspection of time distributions for each frame indicated that while the means were variable, the general shape of the distributions was quite uniform throughout. As is typical of latency data, this shape was unimodal with a pronounced tendency toward positive skewness. Figure 1 shows an idealized curve which is typical of the distribution found for each frame. As can be noted from the figure, intervals on the physical time scale which include the lower, middle, and upper thirds of the distribution are quite different. The percentile points bracketing the distribution into thirds, therefore, did not represent equal

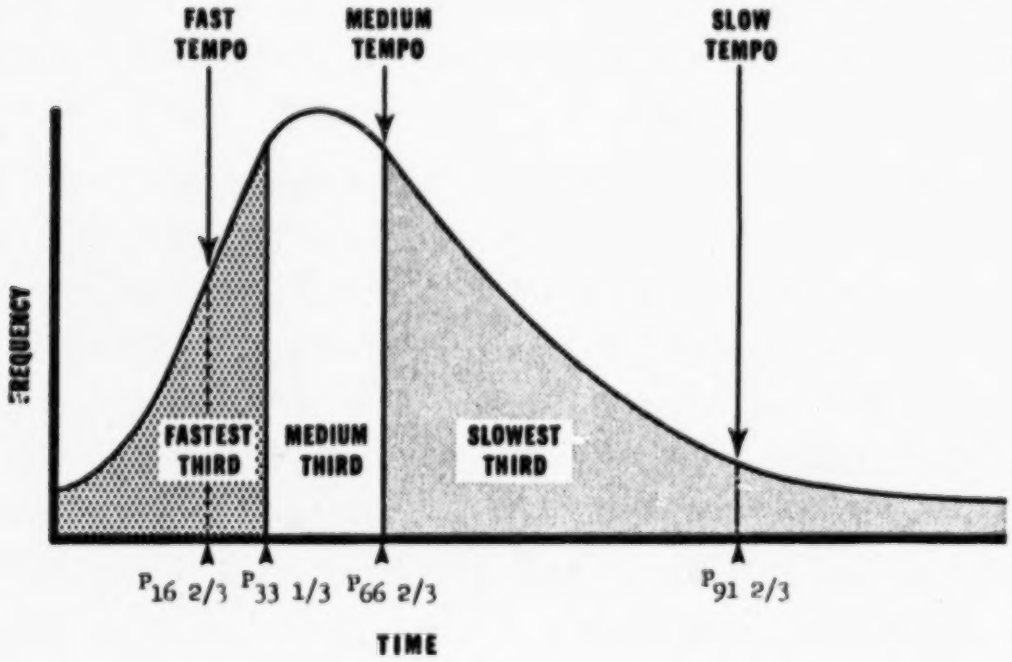

Fig. 1

An idealized frequency distribution
of times taken to complete a program frame

time intervals. It was felt that the time requirements of Ss in the target population would be better approximated by selecting tempo levels based on the percentile points on the time distribution which divided the entire group into equal thirds rather than on the size of the time intervals.

It can be seen from Figure 1 that the slow tempo level chosen ($P_{91\ 2/3}$) was not based on the slowest S in the slowest third of the distribution. To have selected a tempo based on the time of the very slowest worker would have produced an unreliable estimate of the time requirements of slow workers in the target population. This alternative was therefore rejected as being imprecise and indeed, impractical. The value chosen ($P_{91\ 2/3}$) was faster than that adopted by only 25 percent of the Ss in the slowest third of the distribution. The medium tempo, on the other hand, was selected on the basis of the slowest time ($P_{66\ 2/3}$) in the middle third of the distribution and, thus, it was expected that this tempo would accommodate all but the majority of slow workers. The fast tempo chosen was $P_{16\ 2/3}$ with only 50 percent of the upper third having been faster. The selection of the slowest time of the upper third of the distribution would have resulted in a tempo which, on the absolute time scale, would have differed little from the medium level. On the other hand, selection of the very fastest time would have resulted in a tempo which could accommodate only the fastest person. Hence, P_{50} of the upper third was chosen.

This selection process, applied to each frame, resulted in fast, medium, and slow versions of the Electricity Program with total times of 31, 46, and 58 minutes, respectively. In absolute terms, the duration of the fast version was slightly more than one-half that of the slow version. These times, based on the performance of the pilot Ss, were judged to be a reasonable projection of the time requirements of the Ss who were to participate in the subsequent paced experiment. They were assumed to be estimates of the durations which the fast, medium, and slow workers in the latter group would require if allowed to proceed at a self-selected pace.

Experimental Design

In order to assess the main effects due to the experimentally manipulated variable, tempo, and due to the subject variables, IQ and work rate, and to their possible interaction, a 2x2x3 factorial design, illustrated in Figure 2, was employed. As shown, there were three levels of tempo, two levels of work rate,

and two levels of IQ. A separate control condition was included in which student work pace was self-selected. This condition was included to serve as a baseline against which the performance of the various externally-paced groups could be compared.

The selection of Ss for inclusion in the factorial design was restricted to those whose performance on posttests for the self-paced Atomics and Force programs indicated they had met a minimum of learning, in this instance a posttest score of at least 70 percent. This restriction was imposed so that an S's work rate on the self-paced programs could be treated as a valid measure of his time requirement to learn a given amount of material. On the other hand, it is undetermined whether work rates which were accompanied by poorer performance adequately reflected an S's needs. Any interaction found between tempo and such possibly non-valid measures of work rate could have produced different problems of interpretation. Therefore, only those Ss who "qualified," i.e. reached 70 percent (or better) achievement were included in the experiment and interaction between externally controlled tempo and work rate differences based only on qualifiers could more readily be interpreted.

Assignment of qualifying Ss to the cells of the experimental design was accomplished in the following manner. Median scores of the IQ and work rate distributions for all qualifers were obtained. With a high-low cutting point for each variable based on these values, the group was then sorted into four categories of Ss: high-IQ-fast, high-IQ-slow, low-IQ-fast, and low-IQ-slow.

TEMPO

		SLOW	MEDIUM	FAST	---	SELF-PACED
FAST WORK RATE	HIGH IQ				---	
	LOW IQ				---	
SLOW WORK RATE	HIGH IQ				---	
	LOW IQ				---	

Fig. 2. Randomized blocks design for assignment of Ss to experimental treatments.

The Ss of each of the four categories were then randomly assigned to each of the three tempo levels or to the self-paced condition. The final design included 12 cells for the fixed tempo conditions in addition to the four cells for the separately-considered, self-paced condition. (See Figure 2.)

Procedure

The administration of all preliminary, self-paced programs occurred in the classrooms.

The Ss were instructed to work at any pace they desired but to strive for accuracy. They were not told that they were being timed, and Es went to some pains to avoid making the timing obvious. During Days 3 and 4, records were kept of the total time to complete the Atomics and Force programs, providing two time scores for each S. These data provided an estimate of the stability of individual work rate over two separate programs, taken on separate days. In addition, they yielded a total-time-to-complete score which was employed as a basis for assigning Ss to slow or fast cells in the design of the main experiment.

The general order and spacing of these sessions is indicated in Table 1.

TABLE 1

Schedule of Administration of Preliminary Materials in the Schools

Day	Tasks	Approximate Length of Session
1	Pretests on the Atomics, Force, and Electricity programs; and a two-part Preprogram	2 hours
	1 day delay	
2	Reading Comprehension Test	1 hour
	1-6 day delay	
3	Atomics Program and Posttest	2 hours
	1-4 day delay	
4	Force Program and Posttest	2 hours

A total of four sessions was required for the administration of all preliminary self-paced programs and their criterion tests. While the order of administration was identical for all classes, the scheduling of the intertask intervals varied slightly among classes to accommodate the requirements of the schools. An interval of 17-21 days elapsed between the final self-paced session and the paced experiment at the television studios of WQED. All of these sessions were conducted during April and May of 1963.

Experimental presentations. - This experiment constituted an exploratory investigation of the effects of fixed tempos on group performance. Accordingly, the least expensive media congruent with the aims of the study were chosen: slide transparencies were used in the fixed tempo conditions, and programmed booklets were used in the self-paced control condition.

Each frame of the Electricity Program and its confirmation was typed on a macro-typewriter. A number of diagrams were used in the program and these were drawn beneath the written portions of the appropriate frames. This master copy was used to make the slides and to print the booklets for the control or self-paced condition. In all, there were 198 3x4 inch Polaroid transparencies displayed: 96 frames, 96 confirmations, plus three warm-up frames with confirmation. The slides were projected rear-screen, the images enlarged to approximately 6x8 feet.

Each S was provided with a work booklet on which to write his responses. The booklets were 4x6 inches, bound with plastic. Each page in the booklet was numbered and contained blanks corresponding to the blanks in each of the numbered frames which were presented on the screen. A colored cover flap was attached to the right-hand margin of each booklet, such that it could be placed over the booklet when the confirmation frames were displayed. The flap insured that Ss did not copy the correct responses and also cued them to attend to the confirmation portion of each frame being presented on the screen.

Each group of Ss was seated at desk-chairs before the screen. Instructions were: to read each frame, write responses in the booklets, and to cover the page with the colored flap when cued to do so.

A buzzer was employed on each frame to indicate that half of the time allotted had elapsed. Since the exposure intervals were variable from frame to frame, this signal helped the Ss to adjust to the particular tempo involved

and budget their reading and writing time on each frame. In addition, a verbal signal was given to cue Ss to stop writing and check their answers when the confirmation frames appeared.

The exposure times on each frame and confirmation were controlled by E with a stopwatch. The projector operator changed slides as directed. The change from slide to slide was rapid so that intervals between slides were negligible. The slides were magazine-loaded so that it was possible to proceed through the entire set without pauses, thus maintaining the tempo of the lesson throughout.

At the conclusion of each lesson, booklets were collected and the 27-item Electricity posttest was administered. (See Appendix A.)

During each of the fixed tempo sessions, a portion of the self-paced control group was run in a separate studio. These Ss took the Electricity program in booklet form, much the same as the previous programs that they had taken in their respective classrooms. The printing, in this case, was done from the same master copies which had been photographed to make the slides. These Ss were instructed to spend as much time as they needed but to strive for accuracy. Completion times were observed and recorded by monitors. The posttest was administered immediately upon completion of the program.

All of the experimental presentations described in this section were completed on a Saturday at the studios of WQED. The first session began at 10:00 A.M. and each of the next two sessions were run consecutively; the entire process requiring about five hours.

On the sixteenth day following the Saturday sessions, the Electricity posttest was readministered to the Ss in their classrooms. This administration was designed to test Ss for retention of the material they had learned during either the fixed-paced or self-paced sessions.

RESULTS

The results of this experiment will be presented in two parts. The first deals with the effects of variations in a fixed tempo on performance. The second presents a comparison between fixed-paced and self-paced instruction.

I. The Fixed Pace Experiment

The results of the randomized blocks assignment of Ss across the three tempo conditions are summarized in Table 2. The separation between high and low IQ levels was 12.8 IQ scale points; that between fast and slow work rate levels 16.9 minutes, (the measures of work rate having been obtained from the self-paced Atomics and Force programs). The mean difference between IQ levels represents 1.66 standard deviations; that between work rate levels, 1.58 standard deviations, both based on the 60 Ss sampled. Table 2 also reveals that high and low IQ levels were well matched for work rate; similarly fast and slow work rate levels were well matched for IQ. This was verified by separate analyses of variance with IQ and work rate as the dependent variables. Subjects in the three tempo conditions did not differ significantly with respect to either IQ or work rate. These analyses summarizing the results of the matching process can be found in Tables 1 and 2 in Appendix B.

TABLE 2

Summary Results of the Matching of Ss
by IQ and Work Rate
N = 60

	separation between levels on each independent variable			
Levels of Independent Variables	IQ (Otis Group) Mean	S.D.	Work Rate (minutes) Mean	S.D.
Slow Tempo	112.90	8.60	86.25	12.27
Medium Tempo	113.80	7.62	86.30	10.73
Fast Tempo	113.20	7.25	86.10	9.52
Fast Work Rate	113.43	8.06	77.77	6.97
Slow Work Rate	113.17	7.49	94.67	6.10
High IQ	119.70	3.98	85.73	10.20
Low IQ	106.90	4.54	86.70	11.36
Overall	113.20	7.72	86.22	10.71

The Effects of Variations in Tempo on Performance

Variations in externally controlled tempo might be expected to influence the performance measures typically observed in instructional research, namely, the number of errors a student makes on a program, the score he receives on an immediate test, and the score he receives on a test administered after a delayed period. Variations in the latter two measures, in addition to their possibly being affected by variations in tempo, may also be affected by other variables, not least of which is errors made during the program. Thus, of the three performance measures, the one which can most immediately, most directly and hence most clearly reflect variations in tempo is errors made during the program. The mean number of errors for each of the three tempo conditions are summarized in Table 3. As might be expected, the increase in tempo from slow to fast was accompanied by consistent increments in errors. Expressed as ratios of the total number of errors possible (152), error rates went from 8 percent to 10 percent and, finally, to 16 percent for the fast condition. Thus, although their absolute values were not high, error rates steadily and significantly increased as the tempo increased. Since the distribution of raw error scores was markedly skewed, the analysis of variance which was performed to assess the statistical significance of the difference among conditions used scores which were transformed into a logarithmic scale, according to the formula: $X^1 = \log (X+1)$. The results of this analysis are summarized in Table 4 and it can be seen that tempo differences were significant beyond the 1 percent level.

The effect of tempo on immediate posttest scores is summarized in Table 5 on page 22. It may be seen that although the scores were generally very high, with the overall average (24.1) being nearly 90 percent of the total possible, the mean scores declined as tempo increased. Non-parametric tests were employed to assess the reliability of these differences, since the analysis of variance model was inappropriate, the distribution of scores being extremely skewed with many scores piled up at the 100 percent level (27 points). A Kruskal-Wallis non-parametric analysis of variance revealed no overall significant difference among tempo conditions ($H = 3.39$, one-tailed $P = .18$). However, a Rank Sum Test of the difference between the two extreme conditions indicated that the fast tempo produced significantly lower scores than did the slow tempo. On a one-tailed test $P = .036$.

TABLE 3

Summary Results for Errors
by Levels of Each Independent Variable
N = 60

Levels of Each Independent Variable	Mean	S.D.
Slow Tempo	11.90	9.08
Medium Tempo	15.50	11.20
Fast Tempo	23.90	18.76
Fast Work Rate	14.53	14.12
Slow Work Rate	19.67	14.36
High IQ	9.97	6.18
Low IQ	24.23	16.60
Overall	17.10	14.35

TABLE 4

Summary of the Analysis of Variance
for Log Errors
N = 60

Source	D.F.	M.S.	F
A (Tempo)	2	.38154	5.08**
B (Work Rate)	1	.58028	7.71**
C (IQ)	1	2.19131	29.12***
AB	2	.08035	1.07
AC	2	.02153	
BC	1	.03228	
ABC	2	.00421	
Within	48	.07503	

**significant at .01 level

***significant at .001 level

TABLE 5

Summary Results for Posttest Scores
by Levels of Each Independent Variable
N = 60

Levels of Each Independent Variable	Mean	S.D.
Slow Tempo	25.2	2.44
Medium Tempo	23.8	4.20
Fast Tempo	23.3	4.03
Fast Work Rate	24.5	3.64
Slow Work Rate	23.6	3.74
High IQ	25.8	1.48
Low IQ	22.3	4.40
Overall	24.1	3.73

The means of the 16-day retention test are shown in Table 6. Comparing them with those of the immediate posttest, we note that their rank order is the same, but an overall drop in performance level is apparent, to a mean of about 69 percent. The distribution of retention scores, unlike the immediate posttest scores, appeared close to normal with little evidence of heterogeneous cell variances. An analysis of variance was therefore performed on these scores, the results of which are summarized in Table 7. Although the mean retention scores declined as a function of increasing tempo, as they did on immediate posttest socres, the difference among tempo conditions was not significant.

The Effects of Variations in IQ on Performance

Across all the fixed-tempo conditions, ability differences led to significant differences in all three performance measures. Inspection of Table 3 reveals that the high IQ Ss committed fewer errors than did the low IQ Ss, less than half as many. The analysis of variance, summarized in Table 4, indicated that this difference was significant ($P < .001$).

The superiority of the high IQ Ss was also shown on the immediate posttest. The median scores of the high and low IQ groups were 96.3 and 69.4 percent, respectively. The difference proved to be significant when analyzed by a Rank Sum Test ($P < .001$).

TABLE 6

Summary Results for Retention Scores
by Levels of Each Independent Variable
N = 60

Levels of Each Independent Variable	Mean[1]	S.D.
Slow Tempo	20.05	4.64
Medium Tempo	18.20	7.27
Fast Tempo	17.45	5.61
Fast Work Rate	20.17	5.31
Slow Work Rate	16.97	6.20
High IQ	20.00	5.82
Low IQ	17.13	5.94
Overall	18.57	5.94

[1]Total points possible = 27

TABLE 7

Summary of the Analysis of Variance
for Retention Scores
N = 60

Source	D.F.	M.S.	F
A (Tempo)	2	35.81667	1.19
B (Work Rate)	1	153.59999	5.12*
C (IQ)	1	123.26667	4.12*
AB	2	50.50000	1.68
AC	2	38.31667	1.28
BC	1	1.06667	-
ABC	2	57.31661	1.91
Within	48	30.05833	-

*significant at the .05 level

The IQ effect was also shown on the retention test, as shown in Table 6. The scores of the high Ss were significantly higher, as assessed in this instance by an analysis of variance. (See Table 7.)

The Effects of Variations in Work Rate on Performance

Subjects who were characterized as fast or slow on the bases of the work rate they adopted on the self-paced program differed, in some instances significantly, on the performance measures obtained during and after the fixed paced presentations. Tables 3 and 4 reveal that the habitually faster workers (under self-paced conditions) responded to the externally paced lessons with fewer errors than did the slower workers. ($P < .01$). Fast Ss were also superior to slow Ss on immediate posttest scores. The median scores were 96.3 and 92.6 percent for fast and slow Ss, respectively. The difference in this instance, assessed by a Rank Sum Test, fell short of the 5 percent level of significance ($P = .0789$). On the retention test, however, the fast Ss outperformed the slow Ss. The results of the analysis of variance (Tables 6 and 7) showed this difference to be significant ($P < .05$).

Interactions Among Independent Variables

No significant interactions were found between tempo and either IQ or work rate. Suggestive trends were revealed, however, particularly for error data. Since errors most directly reflect the effects of variations in tempo, it is instructive to plot the error data showing the most pronounced interactive trend. As can be seen from Figure 3, the performance of the high IQ Ss was less influenced by increases in tempo than it was for low IQ Ss. While the number of errors increased for both groups of Ss, the increase was considerably more pronounced for the low IQ Ss. The same tendency was observed for immediate posttest scores although here the separation between high and low IQ Ss under the fast tempo was less wide. On retention scores even this degree of separation was no longer present. Although there were interactive trends between tempo and work rate, and among tempo, IQ, and work rate, these were neither significant nor consistent.

Adjustments for pretest. - While IQ and work rate were well equated across conditions, a check of the distribution of pretest scores revealed that they were not well equated across conditions. (See Table 3, Appendix B.) The IQ and work rate levels displayed particular imbalance in this regard, with the higher IQ and faster Ss having had the higher pretest scores.

In order to assess the effects of the independent variables free from

pretest effects, analyses of covariance were performed for both the error and retention measures. Tables 4 and 6 in Appendix B summarize the mean number of errors and the mean retention scores by levels of each independent variable after each of these measures was adjusted for pretest score. The adjusted error scores are similar to the unadjusted scores (Table 3) with somewhat smaller separation between IQ and between work rate levels. The covariance analysis of log error scores, summarized in Table 5 in Appendix B, reveals that while the IQ and tempo effects remain significant, that of work rate dropped below the .05 level.

The adjusted retention score means are somewhat different from the unadjusted scores. The covariance analysis of these scores (Table 7 in Appendix B) indicates that both IQ and work rate effects dropped below the .05 significance level, and that tempo again failed to be significant as did all the interactions.

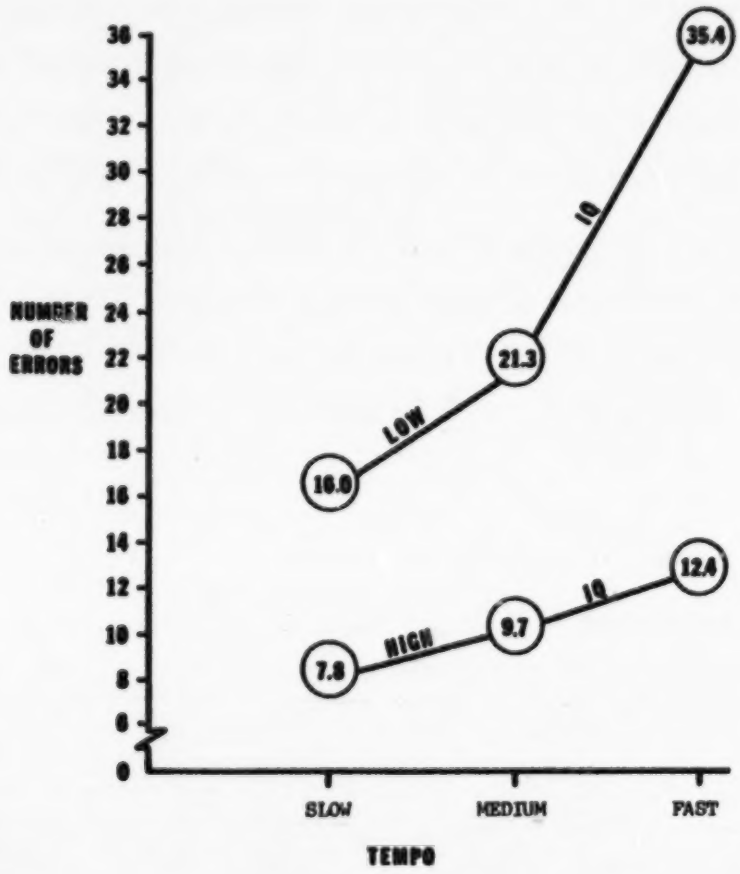

Fig. 3

Interactive effects of IQ and Tempo on errors committed during the program

II. Comparison of Fixed-Paced and Self-Paced Presentations

It will be recalled that the original sample of Ss was assigned at random to four treatment conditions. Three of the conditions were fixed-paced with the fourth a control condition in which the Ss were presented with the Electricity program in booklet form and allowed to proceed at their own pace. Two types of analyses were performed between fixed- and self-paced conditions. In the first analysis, 30 Ss from the self-paced group were compared with 30 Ss from the slow tempo group whose average scores on the IQ, Work Rate, and Pretest measures were virtually identical. This analysis permitted a comparison of the relative effectiveness of the slowest fixed pace condition with the self-paced condition. In a second analysis, matched groups of 29 Ss each were identified from the self-paced condition and from the various fixed tempo levels which were "optimal" for particular Ss. The optimal group was defined as those Ss whose work rate estimates (from the Atomics and Force programs) matched the fixed pace (tempo) of the condition to which they were assigned. Thus, this group included fast workers who had been assigned (at random) to the fast tempo condition, medium-speed workers to the medium tempo condition, and slow workers in the slow tempo condition. This second analysis permitted a comparison of the relative effectiveness between a self-paced group and a group of Ss assigned to fixed pace conditions which were presumed to be optimal for them based on estimates of their previously self-adopted work rates.

Table 8 summarizes the results of the matching procedure with respect to pretest, IQ, and work rate levels of the groups. The sections to follow will deal with comparisons between these self-paced and fixed-paced groups on the dependent measures, errors, immediate posttest,and retention scores.

TABLE 8

Summary Results of the Matching of Ss by IQ, Work Rate, and Pretest Scores

MATCHING VARIABLE	"Slow" Fixed Tempo (N=30)		Self-Paced (N=30)		"Optimal" Fixed Tempo (N=29)		Self-Paced (N=29)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
IQ	114.0	7.8	114.5	8.7	113.8	9.3	114.3	8.5
Work Rate	88.0	12.9	89.4	11.9	87.9	11.1	89.1	11.4
Pretest Electricity	10.1	4.1	10.0	5.4	10.1	5.3	9.45	5.2

Slow Fixed-Tempo vs. Self-Pacing

The slow fixed-tempo group and the matched self-paced group were compared for the number of errors committed during the Electricity program. Since the fixed tempo of the slow condition was designed to accommodate nearly all Ss, no particular difference would be expected between the two. The two groups were compared by means of an independent group t-test of the log (Errors + 1), the positive skewness of the Error distribution having dictated this transformation. Inspection of Table 9 reveals that the mean error score of the self-paced group exceeded that of the slow fixed tempo group. The difference approached, but did not quite reach the .05 level of significance.

The two groups were next compared for scores on the immediate posttest. A non-parametric Rank Sum Test indicated that the obtained difference between medians of 7 percent, with the slow fixed tempo group outperforming the self-paced group, exceeded the 5 percent level of significance. (See Table 9.)

The last comparison between the two groups was made by a t-test of the retention test scores. The slow tempo group was again found to be superior to its matched self-paced counterpart. The mean difference of 11 percentage points was significant beyond the 1 percent level. (See Table 9.)

TABLE 9

Summary of the Analyses of Differences
Between the Slow Tempo Group and the
Self-Paced Control Group
($N = N_2 = 30$)

DEPENDENT MEASURE	Slow Tempo	Self-Paced	Difference	t	p
Mean Number of Errors	10.03	12.00	1.97	1.80[a]	.08
Mean Retention Score in Percentages	75.83	64.83	11.00	3.95	.004
Median Immediate Posttest Score in Percentages	96.00	89.00	7.00	-2.51[b]	.0061[c]

[a] based upon log (Errors + 1) transformed scores

[b] this is a z value

[c] one-tailed probability

Optimal Tempo vs. Self-Pacing

A set of comparisons, analagous to those just described in the preceding section, was performed between the externally-paced group defined as "optimal," and its matched, self-paced counterpart. While not every S in the "optimal" group worked under an imposed tempo which was presumed to accommodate his work rate perfectly, the cells selected to constitute the "optimal" group represented a fair approximation of fixed paces which matched previously self-adopted paces.

A summary of the comparisons made between the optimal and self-paced control groups is given in Table 10. It may be observed that while the self-paced group made fewer errors than the optimal group, the difference between them did not approach statistical significance. On the retention measure, the optimal group was slightly favored. But, this difference was also not statistically significant. The difference which arose in immediate posttest scores, on the other hand, was significant (one-tailed P = .0064) and favored the optimal externally paced group.

TABLE 10

Summary of the Analyses of Differences
Between the Optimal Tempo Group and the
Self-Paced Control Group
($N_1 = N_2 = 29$)

DEPENDENT MEASURE	Optimal Tempo	Self-Paced	Difference	t	p
Mean Number of Errors	13.00	11.67	1.33	.09[a]	.86
Mean Retention Score in Percentages	66.10	63.63	2.47	.56	.62
Mean Immediate Posttest Score in Percentages	96.0	89.0	7.00	-2.49	.0064[b]

[a] based upon log (Errors + 1) transformed scores

[b] one-tailed probability

DISCUSSION

The discussion to follow will cover the major findings of this experiment with particular attention to: (1) the effects of variations in fixed tempos on performance; (2) the role of IQ and work rate under externally controlled pacing conditions; and (3) a comparison between a self-adopted and an externally controlled pace at which a student works on a program.

The Effects of Variations in Tempo on Performance

Performance during work on a program, rather than after its completion, is most directly and most clearly affected by variations in externally controlled tempo. The faster the presentation, that is to say, the shorter the duration of stimulus exposure and of the opportunity to respond, the more difficult do responses become and more likely are errors to be committed. The increasingly fast tempo levels employed in this experiment were indeed accompanied by increases in average error rates, increasing from 7.8 percent in the slow condition to 10.2 percent in the medium speed condition to 15.7 percent in the fast condition. This represented a doubling of errors as the allotted working time was approximately halved.

While it is true that performance deteriorated uniformly as tempos became faster, it is interesting to note that even in the fastest condition, the mean error rate was no higher than 16 percent. This result provides tentative support for the informal observations made of Ss during the administration of the experiment. Subjects in the fast tempo condition appeared to complete their work consistently before the time was up. The "fast" condition, therefore, was perhaps not as fast as it might have been to produce maximally differential results for the different tempos or for Ss varying in ability or in characteristic work rate. The range of fixed tempos sampled in the present experiment, it is true, was wider than has been used in previous studies. The range employed by Lottes, Palmer, and Oakes (1963), for example, was between 80 and 110 percent of an average time. Total times for the three tempo levels in this study were 31.3, 46.1, and 57.5 minutes. If the medium tempo level is taken as the average, then the fast and slow tempos respectively represent 68 and 125 percent of the average time, with the slow tempo having involved nearly twice the time allowed for the fast tempo. The "paced" and "long-paced"

conditions observed in the Silverman and Alter study (1961), though not identified quantitatively, would seem to correspond to the medium and slow tempo levels, respectively, of the present study. There again, the range of tempos sampled was not as wide as that of the present study.

The intended effect of the wider range of fixed tempos selected here was, of course, to approximate more closely the wide range of characteristic work rates observed during the administration of the preliminary programs in which Ss were free to adopt their own paces. (See Report #1.) The pace during the fast condition was designed to exceed the habitual, self-adopted work rate of over 80 percent of the sample. The average work rate adopted by the matched control Ss working on the same materials but at a self-adopted pace was 35.4 minutes. The tempo level designed by the experimenters to be fast (31 minutes), in effect, corresponded more nearly to an average or medium tempo. The similarity between the experimenter-designed "fast" tempo and what turned out to be the average pace which was adopted by the self-paced control group suggests that the pilot Ss used to determine tempo levels may not have represented the same population from which the experimental sample was drawn.

The apparent bias toward a slower work rate than was perhaps indicated for Ss who participated in this experiment undoubtedly contributed to a reduction in the negative effects which increased tempos might have been expected to have on student errors. Despite this bias, significant differences in errors were found among the three tempo levels with the fast tempo, as expected, producing the largest number of errors. Thus, it appears that, with the cuing level provided by lesson content held constant across tempo levels, but with cuing level as influenced by stimulus exposure times increasingly reduced, decrements in performance resulted. Carried to the logical extreme, i.e., increasing the tempo until exposure was subliminal, it is perfectly obvious that any possibility of correct responding would be precluded. For practical purposes, however, nearly complete deterioration might be expected as exposure times approached the limits of Ss' reading speeds. There was, however, little danger of this occurrring in the present study, given the fact that the tempos employed apparently were based on non-representative, slower pilot Ss. Even though restricted by these limitations, increases in tempo nevertheless did significantly affect error rates.

Errors are, of course, not the programmer's ultimate concern. His aim is to produce maximal achievement. Toward that end he attempts to keep error rates

relatively low because, as a reasonably broad consensus would have it, errors and achievement are negatively related. If errors and achievement are negatively related, and the results of Report #1 in this series provide empirical support for the position that they are, then variations in tempo must, in part at least, affect achievement through its more direct effect on errors. When experimental manipulations produce no reliable effects on achievement, as the manipulation of tempo levels did not here, a first line of inquiry is to examine the magnitude of the error rate. Were error rates in any of the conditions sufficiently high to have affected achievement? Klaus (1964) has suggested that error rates of less than 20 percent may not seriously impair achievement. Report #1 in this series presented evidence showing that error rates of lesser magnitude can still influence achievement results. It has also been shown that,by increasing the cuing level, error rates can be systematically kept low. This is not invariably accompanied however by improved achievement (Krumboltz 1964).

There is little empirical evidence to suggest what the critical error rate is which will result in achievement decrement. It is highly likely that it will vary from program to program depending, perhaps, on such factors as the programming style, the subject matter being taught, the behavioral strategy being implemented, etc.

In view of the rather complex interrelationships between errors and achievement, the failure to find reliable achievement differences among tempo levels, even though error differences were reliable, should create no particular suprise. It is reasonable to conclude from the present findings that increases in tempo produce performance decrement during work on the program itself. Impairment of achievement would be expected to result when such decrement becomes sufficiently high.

Although this experiment was not designed to assess the issue, it is also conceivable that tempo variations might have effects on achievement independent of their effects on errors. For example, variations in spacing of response practice which result from variations in tempo might not affect errors on the program but might influence immediate achievement levels or perhaps retention levels. It is more likely to be the case however, that if tempo can affect performance, it will do so through its direct and immediate effect on errors. Thus, the selection of appropriate fixed tempos must, it seems clear, be

empirically based to preclude error rate levels which can lead to lowered achievement. The object of such a determination would, of course, be to accommodate individual differences among students.

The Role of IQ and Work Rate in Fixed Paced Instruction

It has been shown, as a general finding, that performance decrement results from increases in tempo. Another primary goal of this study is to determine whether, as a result of these increases in fixed tempos, the performance of students varying in abilities and work habits is differentially impaired. The results of this study do demonstrate that students varying in ability, as measured by such typical IQ instruments as the Otis group test, and varying in characteristic work rates, as estimated on the basis of performance on two self-paced programs, do respond differentially to fixed paced presentations.

With characteristic work rates controlled, it was found that, across all the fixed tempo conditions, above average students generally outperformed their less able fellows. Moreover, as tempos increased, the gap between them even tended to widen.

As exposure durations of stimulus materials and the opportunity for responding shorten, it would be expected that heightened response difficulty would be experienced by all students. However, since response difficulty as a function of the cuing value of lesson content is already apt to be different for the above and below average student, even under self-paced conditions, the reduction of cuing value by shortening of exposure times might be expected to be non-uniform in its effect for students of varying ability. Students already having more difficulty responding to lesson materials might be expected to be more seriously handicapped by reduction in cuing levels than students experiencing less difficulty. It is, of course, not possible to describe on the basis of the data available precisely what this interactive function might be. Increases in tempo, however, might be thought to create out of exactly the same lesson content a program of different step-size for students varying in ability. Thus, while any given frame in a program may, to begin with, constitute a large or a small step for students varying in ability, variations in tempo may in addition be another factor capable of increasing its size. Its effects may possibly be differentially felt.

Differences among students in characteristic, self-adopted work rates also generally led to differences in performance under all fixed tempo conditions.

In addition, it was found that with IQ controlled, characteristically fast students outperformed their slower counterparts. This was the opposite of the findings presented in Report #1. There, with both qualifiers and non-qualifiers participating, it was found that under self-paced conditions, students who worked at a slower pace performed better than their faster counterparts. Thus, one of the principal differences between the self-paced and fixed tempo investigation was the inclusion of non-qualifiers in the self-paced study and their absence in the fixed-paced study. The non-qualifiers under self-paced conditions, were, to a large extent, fast workers. Those who did best under fixed paced conditions were characteristically fast qualifiers. It might be agreed that the difference between fasts and slows under fixed tempos is due to changes in step-size. When tempos are increased, step-size is perhaps not increased uniformly for fast and slow students. Characteristically fast students who can reach satisfactory achievement levels in self-paced instruction, despite the fact that they are fast, do not seem to be as much impaired by increases in fixed tempo.

Consistent interactions between tempo and work rate were not, however, found in the results of this study. It was found only that fast students outperformed their slow counterparts. A number of reasons suggest themselves. First, it should be recalled that the tempo levels employed, while representing a wider range than those employed in other studies, still did not appear to produce a fast condition which maximally taxed student capacity to keep pace. Interactive effects may have been precluded thereby. Second, while self-adopted work rates tend to be consistent, they may still be capable of modification. Thus, while a student may be characteristically slow on several programs under self-paced conditions, it might still be possible to speed him up without serious loss. The data of the present experiment do not provide sufficient evidence on this point, but it might be conjectured that bright but slow workers may be speeded up without serious consequences. These various possibilities may have contributed to the failure to find significant interactions particularly at the faster fixed tempo, where the separation between fast and slow students might be expected to have been greatest. At the slowest tempo, where all students would be accommodated, no differences would be expected to occur at all.

Future research in which tempo variations are wide enough to produce maximal effects may be required to disclose whether there are interactions

between such individual difference variables as IQ or characteristic work rate and fixed tempos. Meanwhile, it may be concluded on the basis of the present results that, in general, characteristically slow and fast workers respond differentially to learning under fixed tempo conditions. Fast qualifiers under self-paced conditions are generally less impaired under fixed tempo conditions.

Self-Paced vs. Fixed-Paced Conditions

It might have been expected that the students who worked under self-paced conditions in this study would have done as well or better than the fixed-paced group. They, after all, were "qualifiers." They had demonstrated that they could, when allowed to do so, adopt a pace compatible with moderately high achievement. By being allowed to pace themselves in the main phase of the experiment each student would be expected, on the basis of his previous performance, to adopt a pace congenial to him and still compatible with high achievement. Instruction would be, many would claim, ideally individualized.

Students in the self-pacing group, as it turned out, adopted a pace comparable to the fast, fixed pace. As a result, it would appear, their achievement scores, although high, were not as high as the slow fixed tempo group and were different from the posttest scores of the "optimally" paced group. Thus, despite the fact that they were reasonably well qualified self-pacers, when they adopted their own pace in the main experiment, they were outperformed by students who were paced by the experimenter-controlled, slow presentation and by "optimally" paced students.

When a pace is fast, whether self-adopted or externally imposed, it can result in too high an error rate. In either instance, the cuing level may be significantly reduced. Under fixed-paced conditions, stimulus exposure durations may be too brief to provide adequate cuing. Under self-paced conditions, work habits may be too careless to provide adequate cuing. In the former case, the needed remedial action is quite obvious. In the latter case, on the basis of the somewhat limited evidence presented here, it would appear appropriate to employ fixed pacing for those who, for whatever reason, do not on their own adopt an appropriate pace.

It will be remembered that the Ss in this study were eighth-graders. The findings reported here may ultimately be shown to be restricted to this age group (and in all liklihood to younger students as well). Working too fast may be symptomatic of low motivation to learn or of poorly developed work habits

which may indeed be more characteristic of younger age groups. Whatever the explanation, the fact that some students do work at a pace which is too fast and which impairs learning effectiveness calls for techniques which will slow it down until it is compatible with high achievement. This would seem to be indicated for groups at any age level who are empirically shown to require it. However, it must also be shown empirically that students who are not qualifiers under self-paced conditions actually improve under fixed paced conditions.

CONCLUSION

It is clear that the pace at which a student works on a program can be non-adaptive whether it is self-selected or externally imposed. Under self-paced conditions students can on their own adopt a pace which is too fast to be compatible with high achievement. Similarly under fixed-paced conditions they can be forced to work at a pace which is too fast to be compatible with high achievement. The remedy for the latter problem is quite clearly apparent: a slower, fixed pace can be selected that is compatible with high achievement. It is possible for fixed-paced presentations to select the pace at which, on tryouts, a predetermined percentage of Ss in a pilot group attains a predetermined achievement level.

The solution to the former problem concerning the non-adaptive pace at which the self-paced group works is not so apparent. The results of the present experiment have not show that people who performed poorly under self-paced conditions improved under fixed paced conditions. The experiment was not designed to do so. They have shown only that fixed pacing when sufficiently slow can produce higher average achievement levels than self-pacing. The fact that controlling the pace at which "qualifiers" worked resulted in performance superior to that of "qualifiers" who worked at a self-adopted pace, strongly suggests, however, that it might also prove effective for non-qualifiers, those most in need of an alternative to self-pacing. Their achievement levels certainly allow more room for improvement than was possible for the self-paced qualifiers studied here. A research design addressing itself explicitly to this problem must of course include non-qualifiers in the sample.

The present study has merely served to provide evidence as to the effect which increases in tempo might have on the performance of qualifiers. It has also served to show that even the performance of qualifiers whose pace is externally controlled can be superior to that of qualifiers who adopt their own pace. When sufficiently slow, it can lead to performance levels superior to that occurring under self-paced conditions. While achievement levels improve as a result of a slow enough fixed tempo, efficiency necessarily suffers. High group achievement requires a slow, fixed pace. Many students, while

performing well at a slow fixed pace may be forced to take more time than they need. There are apparently, in this regard, unavoidable trade-offs.

The optimal individualization of instruction must, it seems clear, take account both of achievement and efficiency. Self-pacing would seem appropriately indicated for those qualifying students who adopt work rates which are compatible with achievement. Those non-qualifiers, who work too fast and who as a result fail to achieve, would be systematically slowed down. Both strategies can insure high achievement levels.

Until now we have discussed those who work too fast. It would also seem appropriate to consider those who work more slowly than is necessary and at a pace incompatible with high efficiency. Those qualifiers who habitually work at a rate which underestimates their work rate capacity might be speeded up. This group of students, it is suggested, would be required to work under fixed-paced conditions at a rate faster than their habitual self-adopted rates. The limits of such potential speedups would, of course, have to be identified for students differing in ability or characteristic work rate. The most likely candidates to be subjected to speed-ups appear to be habitually slow, but bright students.

Thus, individualized instruction would not necessarily be accomplished by allowing students to adopt their own pace. Wherever indicated, fixed pacing might provide more effective individualization of instruction than would self-pacing. When provided with lesson content presented at a fixed pace appropriate for him, a student could demonstrate either higher achievement or greater efficiency than would be the case if allowed to adopt his own pace. Proper individualization would, thus, appear not to be a function of who sets the learning pace. Rather, it may be assumed to have occurred when achievement and efficiency levels, arrived at under either self-paced or fixed paced conditions, approach predetermined levels.

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APPENDIX A

Programmed Materials and Tests

	Page
1. Electricity Program	A-1
2. Electricity Test	A-9

ELECTRICITY PROGRAM*

1.

You are going to learn about electronics. You cannot understand how a radio works until you have learned about ELECTRONICS.

2.

If you wished to understand how a television set works, you would have to learn about ELECTRONICS.

3.

Electronics has to do with the behavior of tiny particles called electrons. The word "electronics" refers to particles called ELECTRONS.

4.

An electronics expert knows a lot about the behavior of particles called ELECTRONS.

5.

Every electron has a negative electrical charge. The minus symbol (-), is often used to represent a NEGATIVE electrical charge.

6.

The particles called ELECTRONS all have a NEGATIVE electrical charge.

7.

There are only two kinds of electrical charges: negative and (+) POSITIVE.

8.

An object with an electrical charge has either a (+) POSITIVE charge or a (-) NEGATIVE charge.

9.

All electrically charged objects can be described as having either a POSITIVE (NEGATIVE) charge or a NEGATIVE CHARGE (POSITIVE CHARGE).

10.

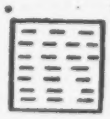
All electrically charged objects must have either a POSITIVE CHARGE OR A NEGATIVE CHARGE.

11.

Because electrons have negative charges, they are themselves often called NEGATIVE charges.

12.

Electrons are often referred to as NEGATIVE charges. This picture shows a group of NEGATIVE CHARGES.



13.

Electrons are often called NEGATIVE CHARGES.

*Subjects made constructed responses for each of the following frames. The frames reproduced here are those which were presented to the subjects as confirmation frames after they had made their own responses. The correct constructed responses appear in capital letters.

14.

A flow of water might be called a river current. Similarly, a flow of electrons is called an electric CURRENT.

15.

Turning on a faucet starts a flow of water. Turning on a flashlight starts a FLOW of electrons, called an electric CURRENT.

16.

When you turn on a radio you are starting a FLOW of electrons called an ELECTRIC CURRENT.

17.

An electric current in a lamp cord may be described as a FLOW of negative charges or a FLOW of ELECTRONS.

18.

When you turn a lamp "on," you are starting an electric current or a FLOW OF ELECTRONS (NEGATIVE CHARGES).

19.

An electric current in a wire is A FLOW OF NEGATIVE CHARGES (ELECTRONS).

20.

Any substance along which an electric current can flow is called a conductor. Copper wire, for example, is called a CONDUCTOR.

21.

Steel is one substance that permits current to flow and is called a CONDUCTOR. Aluminum is another SUBSTANCE that permits current to flow and is called a CONDUCTOR.

22.

Most metals are SUBSTANCES which permit current to flow. That is, most metals are CONDUCTORS of electric current.

23.

A conductor is any SUBSTANCE along which an ELECTRIC CURRENT can FLOW.

24.

A conductor is ANY SUBSTANCE ALONG WHICH AN ELECTRIC CURRENT CAN FLOW (WHICH PERMITS CURRENT TO FLOW).

25.

While electric current flows along a conductor, it does not flow along an insulator. Copper is a conductor, but rubber is an INSULATOR.

26.

Electrons do not flow along a rubber pole because rubber is an INSULATOR.

27.

Insulators do NOT permit the flow of electric current.

28.

A conductor will permit ELECTRIC CURRENT TO FLOW (ELECTRONS TO FLOW), but an insulator DOES NOT PERMIT CURRENT (ELECTRONS) TO FLOW.

29.

The difference between conductors and insulators is that CONDUCTORS PERMIT THE FLOW OF ELECTRIC CURRENT (ELECTRONS), BUT INSULATORS DO NOT.

30.

An electron has a NEGATIVE charge. Electrical charges must be either NEGATIVE OR POSITIVE.

31.

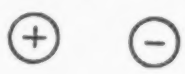
Two negative charges are called like charges. Two positive charges are also called LIKE charges.

32.

The two negative charges in A may be called LIKE charges. The two positive charges in B may also be called LIKE CHARGES.

33.

A positive and a negative charge are not like charges; they are unlike charges. The charges below are NOT like charges; they are UNLIKE charges.



34.

A positive and a negative charge would be called UNLIKE charges.

35.

Figures A and B both show charges which are called LIKE CHARGES. On the other hand, Figure C shows charges which are called UNLIKE CHARGES.

36.

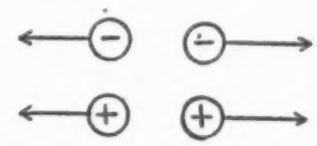
Like charges repel, or move away from, each other. The like charges below REPEL, or move AWAY from, each other.

37.

These like charges REPEL, or move AWAY from, each other.

38.

Like charges always tend to REPEL each other. That is, they tend to move AWAY FROM each other.



39.

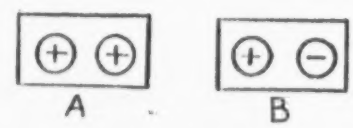
Unlike charges attract, or move toward, each other. The unlike charges below ATTRACT, or MOVE TOWARD each other.

40.

These unlike charges ATTRACT, or MOVE TOWARD, each other.

41.

The charges shown in A REPEL each other, but those shown in B ATTRACT each other.



42.

It is a general rule that like charges REPEL each other, but unlike charges ATTRACT each other.

43.

The general rule of attraction and repulsion is that like charges REPEL each other, but UNLIKE charges ATTRACT EACH OTHER.

44.

The general rule of attraction and repulsion is that LIKE CHARGES REPEL; UNLIKE CHARGES ATTRACT EACH OTHER.

45.

The particles with negative charges are called ELECTRONS. A flow of ELECTRONS along a conductor is called an electric CURRENT.

46.

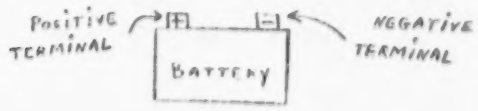
Electric current will flow along a CONDUCTOR, but will not flow along an INSULATOR.

47.

A battery is sometimes used to supply electric current. Portable radios have batteries which supply ELECTRIC CURRENT.

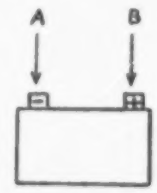
48.

The battery shown below has two terminals. The one with the positive charge is called the positive TERMINAL. The one with the negative charge is called the NEGATIVE TERMINAL.



49.

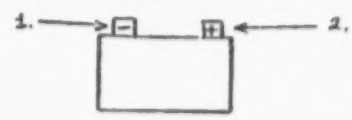
In this figure, A is the negative TERMINAL of the battery, and B is the POSITIVE TERMINAL of the battery.



50.

Label the two parts of the battery:

1. NEGATIVE TERMINAL.
2. POSITIVE TERMINAL.



51.

The negative terminal of a battery is technically called the cathode. An electrician would refer to the negative terminal as the CATHODE.

52.

If you wanted to refer to the negative terminal you might call it the CATHODE.

53.

The technical term for negative terminal is "CATHODE."

54.

The positive terminal of a battery is called the anode. While the negative terminal is called the CATHODE, the positive terminal is called the ANODE.

55.

If you remember that (A+) is a high grade, you will remember that (A)node means the (+), or POSITIVE, terminal of a battery.

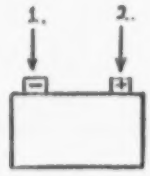
56.

The technical term for the positive terminal is "ANODE."

57.

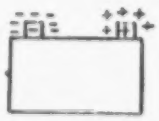
Label the parts of this battery, using the technical terms:

1. CATHODE.
2. ANODE.



58.

The cathode of a battery has many NEGATIVE charges, while the anode has many POSITIVE CHARGES.



59.

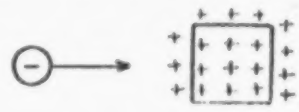
While the anode has a POSITIVE charge, the cathode has A NEGATIVE CHARGE.

60.

Negative charges (electrons) are repelled by other negative charges. Each electron at the cathode is therefore REPELLED by all the other ELECTRONS (NEGATIVE CHARGES).

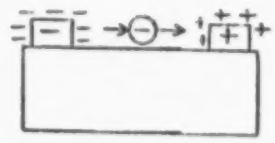
61.

An electron is attracted by positive charges. The single electron below is ATTRACTED by the positive charges.



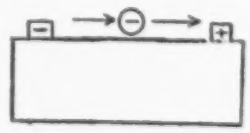
62.

An electron placed between cathode and anode would be REPELLED by the cathode and ATTRACTED by the ANODE.



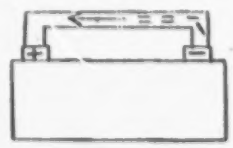
63.

The electron shown below would not move toward the cathode; it would MOVE TOWARD the anode.



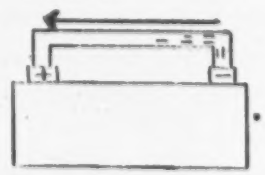
64.

If a conductor is placed between cathode and anode, some of the electrons will flow, from the CATHODE to the ANODE.



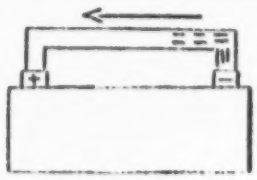
65.

A flow of electrons along a conductor is called an electric CURRENT. This figure shows an ELECTRIC CURRENT flowing between cathode and anode.



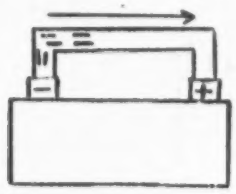
66.

The electrons come from the CATHODE and flow toward the ANODE.



67.

Place an arrow above the wire to show the direction of current flow.

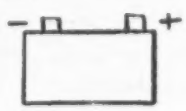


68.

In a battery, electrons always flow from THE CATHODE TO THE ANODE.

69.

When one terminal of a battery has a negative and the other a positive charge, we say there is a difference in charge between them. This battery has a DIFFERENCE in charge between its terminals.



70.

The symbols: + and -, at the terminals, are used to show that there is a DIFFERENCE in charge between the terminals.

71.

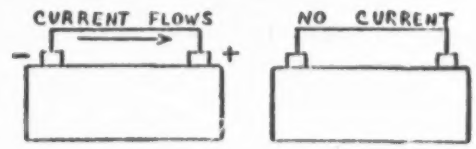
Battery A has a DIFFERENCE in charge between its terminals. Battery B, on the other hand, has no DIFFERENCE IN CHARGE between its terminals.

72.

When there is a positive charge at one terminal and a negative charge at the other, we say there is a DIFFERENCE IN CHARGE between the terminals.

73.

When there is a difference in charge between the terminals, current will flow along the conductor. If there is no difference in charge, NO CURRENT WILL FLOW.

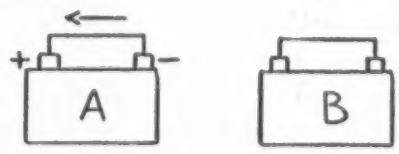


74.

Current will flow through a CONDUCTOR if it is connected between terminals which have a DIFFERENCE in CHARGE.

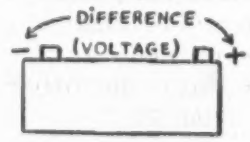
75.

Current does NOT flow in B because THERE IS NO DIFFERENCE IN CHARGE (BETWEEN THE TERMINALS).



76.

A difference in charge between battery terminals is called a voltage. This battery has a difference in charge, or VOLTAGE, between its terminals.



77.

A difference in charge between battery terminals is called a VOLTAGE. A "live" battery has a VOLTAGE between its terminals.

78.

In order for current to flow in a battery there must be a VOLTAGE.

79.

In a battery, a voltage is a DIFFERENCE in CHARGE between terminals.

80.

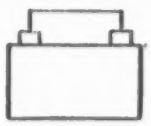
In a battery, a voltage is A DIFFERENCE IN CHARGE BETWEEN THE TERMINALS.

81.

For a current to flow, there must be a difference in charge, or VOLTAGE, between the terminals. Also, the terminals must be connected by a CONDUCTOR.

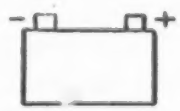
82.

No current flows here because THERE IS NO VOLTAGE (DIFFERENCE IN CHARGE) BETWEEN THE TERMINALS.



83.

No current flows here because THE TERMINALS ARE NOT CONNECTED BY A CONDUCTOR.



84.

In order to get current to flow between the terminals of a battery, two things are necessary:

1. A VOLTAGE (DIFFERENCE IN CHARGE).
2. A CONDUCTOR.

} either order

85.

Voltage is considered to be an electrical "pressure" which causes electric current to flow. The higher the voltage, the higher is this electrical "PRESSURE."

86.

Just as water pressure causes a flow of water, electrical "pressure" CAUSES A FLOW of electric current.

87.

A voltage is considered to be an electrical "PRESSURE" which CAUSES A FLOW of electric current.

88.

A voltage is considered to be AN ELECTRICAL "PRESSURE" WHICH CAUSES A FLOW OF ELECTRIC CURRENT.

89.

The amount of current that can flow depends partly on the amount of voltage. A high voltage can produce more current flow than a LOW voltage.

90.

A low voltage cannot produce as MUCH current flow in a conductor as a HIGH voltage.

91.

The amount of water pressure affects the amount of water that can flow. Similarly, the amount of voltage affects the AMOUNT of electric CURRENT that can FLOW.

92.

Compare a high and a low voltage battery. The high voltage battery can produce MORE (GREATER) current.

93.

If you need a large amount of current to start your car, you would not use a low voltage battery. Instead, you would use a HIGH VOLTAGE BATTERY.

94.

A high voltage battery can deliver more CURRENT than a low voltage battery.

95.

A high voltage battery can produce MORE CURRENT than a LOW VOLTAGE battery.

96.

The amount of voltage affects the AMOUNT of electric CURRENT that can FLOW.

97.

The amount of voltage affects THE AMOUNT OF CURRENT THAT CAN FLOW.

ELECTRICITY TEST

Complete each of the following by filling in the necessary words.

1. Two negative charges always have the same effect on each other: they always _____ each other.

2. There are two kinds of electrical charges. Any one charge must be either 1. _____ or 2. _____.

3. An (electrical) insulator is defined as _____ _____.

4. Electronics is the study of particles which are called _____.

5. An electric current may be described as _____ _____.

6. An (electrical) conductor is defined as _____ _____.

7. The direction of current flow from a battery is always the same: it flows from the _____ to the _____.

8. Two positive charges always _____ each other.

9. The negative terminal of a battery is called the _____.

10. The two things which must be present in order for current to flow between the terminals of a battery are:

    1. A_____ and
    2. A_____.

Electronics Test - continued

11. The term which represents electrical "pressure" is _____.

12. A positive and a negative charge always _____ each other.

13. A one-word term which can be used to describe a difference in charge is _____.

14. The negative terminal of a "live" battery has a large number of _____.

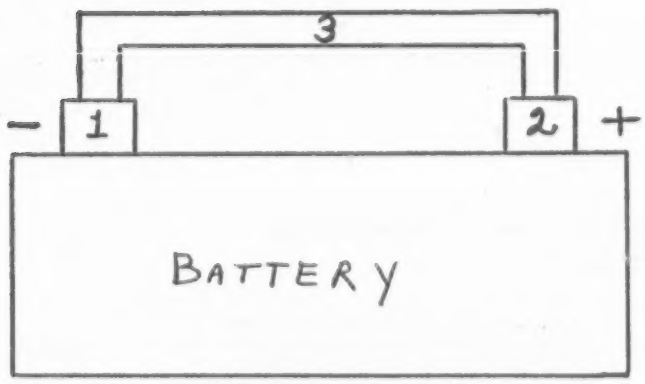
15. The positive terminal of a battery is called the _____.

16. The amount of current flow in a battery is affected by the amount of _____ _____.

17. State the general rule of electrical attraction and repulsion: _____ _____.

18. Write one word on each of the lines below to describe each of the numbered parts of this picture.

1. _____
2. _____
3. _____



APPENDIX B

Additional Results

TABLE 1

Summary of the Analysis of Variance
for the Matching of Ss by IQ
N = 60

Source	DF	MS	F
A (Tempo)	2	4.2000	-
B (Work Rate)	1	1.0667	-
C (IQ)	1	2457.5999	118.00***
AB	2	.4667	-
AC	2	15.2000	-
BC	1	1.6667	-
ABC	2	9.8665	-
Within Replicates	48	20.7250	

***significant beyond the .001 level

TABLE 2

Summary of the Analysis of Variance
for the Matching of Ss by Work Rate
N = 60

Source	DF	MS	F
A (Tempo)	2	.2167	-
B (Work Rate)	1	4284.1500	85.7***
C (IQ)	1	14.0167	-
AB	2	15.6500	-
AC	2	3.8167	-
BC	1	14.0167	-
ABC	2	.5163	-
Within Replicates	48	50.3667	

***significant beyond the .001 level

TABLE 3

Summary Results of Pretest Scores on the Electricity Program
by Levels of Each Independent Variable
N = 60

Levels of Each Independent Variable	Mean	S.D.
Slow Tempo	10.10	4.62
Medium Tempo	11.00	6.46
Fast Tempo	8.80	5.51
Fast Work Rate	11.67	5.07
Slow Work Rate	8.27	5.59
High IQ	12.67	5.57
Low IQ	7.27	4.09
Overall	9.97	5.56

Table 4

Adjusted Mean Error Scores
by Levels of Each Independent Variable
N = 60

Levels of Each Independent Variable	Mean
Slow Tempo	12.02
Medium Tempo	16.44
Fast Tempo	24.97
Fast Work Rate	16.01
Slow Work Rate	18.19
High IQ	13.48
Low IQ	20.72

TABLE 5

Summary of the Covariance Analysis for
Log Errors on the Electricty Program
with Pretest Scores Treated as Covariate
N = 60

Source	DF	MS	F
A (Tempo)	2	.30212	4.77*
B (Work Rate)	1	.17312	2.73
C (IQ)	1	.68905	8.80**
AB	2	.07285	1.15
AC	2	.02878	-
BC	1	.01244	-
ABC	2	.00399	-
Within Replicates	47	.06333	

*significant beyond the .05 level

**significant beyond the .01 level

TABLE 6

Adjusted Mean Retention Scores
by Levels of Each Independent Variable
N = 60

Levels of Each Independent Variable	Mean
Slow Tempo	19.97
Medium Tempo	17.55
Fast Tempo	18.19
Fast Work Rate	19.10
Slow Work Rate	17.08
High IQ	18.30
Low IQ	18.83

TABLE 7

Summary of Covariance Analysis of Retention Scores
on the Electricity Program
with Pretest Scores Treated as Covariate
N = 60

Source	DF	MS	F
A (Tempo)	2	31.35326	1.46
B (Work Rate)	1	14.62469	-
C (IQ)	1	2.99337	-
AB	2	23.95817	1.12
AC	2	26.73127	1.24
BC	1	.56256	-
ABC	2	50.59270	2.36
Within Replicates	47	21.45753	